STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF MICHIGAN.

CONTRIBUTED BY W. B. PILLSBURY.

VII. THE EFFECT OF STIMULI UPON THE LENGTH OF TRAUBE-HERING WAVES.

By C. E. GALLOWAY.

In two papers, published about three years ago, Dr. Slaughter [1] and Mr Taylor [2] showed that fluctuations of the attention stand in close relations to certain physiological rhythms, chiefly the Traube-Hering waves and respiration, and that they are considerably affected by sensory stimulation. These results suggested a series of experiments on the effect of stimuli on the Traube-Hering waves with a view to finding whether or not it coincided with the effect of stimuli on the fluctuations of the attention. The general aim was to secure, if possible, additional evidence for the theory that the two processes have the same physiological basis and also to determine the effect of pleasant and unpleasant stimuli upon one more physiological process. When these experiments were well under way Prof. Pillsbury, who was then investigating the relation of the attention waves to fatigue,[3] suggested a parallel investigation of the Traube-Hering waves to determine whether or not they showed a "diurnal periodicity corresponding to that noted in the attention waves." Accordingly a series of plethysmographic tracings were taken from five of the subjects used by Prof. Pillsbury in his experiments and the results compared with those which he had obtained. A very close correspondence between the two series appeared, but certain apparently anomalous results will require discussion, and reference to the earlier work will be necessary. It seems best, therefore, to begin with a brief summary of the conclusions which may be drawn from the results set forth in all three of these papers so far as they have any bearing on our present work.

Dr. Slaughter's conclusion from his experiments means that "the fluctuations of the attention are in close connection with at least three physiological rhythms." In the great majority

[1] *Am. Jour. of Psy.*, Vol. XII, 313.
[2] *Ibid.*, 335.
[3] *Am. Jour. of Psy.*, Vol. XIV, 277.

of cases they follow the Traube-Hering waves; in some subjects the respiratory rhythm predominates, while in a third class the important thing is a much longer rhythm which is seldom represented in the volume tracings. Since this third wave was found in but one subject, and as in our later experiments Traube-Hering waves of about the same length not infrequently appeared singly or in short series among waves of medium length, it seems needless to set it in a class by itself; and the important result reached is that the periods of fluctuation stand in close relation to the vaso-motor and respiratory processes. In explanation of this relation Slaughter suggested that the activities of the vaso-motor and respiration centres "in some may reinforce the functional activity of the sensory cells." This theory was suggested by the discovery that voluntary effort caused a marked increase in the efficiency of attention, as measured by the ratio of the period of visibility to that of invisibility, while the total wave was shortened; and by the fact that "respiration waves are found in blood pressure tracings and that both vaso-motor and respiration effects are found in the rate of the heart." In the latter the effect noted is probably to be explained by the overflow of impulses from one centre to another while in the former there seems to be a similar reinforcement of the sensory centres by irradiation from the motor centres. The shortening of the total attention wave as a result of voluntary effort will be discussed later.

Last year Bonser,[1] working independently and in ignorance of Slaughter's results, confirmed the parallelism between fluctuation of the attention and the respiratory and vaso-motor rhythms. In five of the seven records which he reproduces the attention waves follow the respiratory rhythm though the vaso-motor waves are quite distinct in the pulse tracings. In the other two the periods of visibility begin, as a general rule, shortly after vaso-constriction commences and continue well into the following vaso-dilation. Strangely enough Bonser makes no mention of the influence of respiration.

The object of Taylor's work was to "throw some light on the much disputed question as to whether the attention waves are of central or peripheral origin" by ascertaining the influence of certain sensory stimuli on the fluctuations. The minimal stimulus was obtained from a Masson disc and the fluctuation recorded by a Marey tambour on a horizontal drum. At each observation a normal record was taken and then a record with stimulation, usually by an induction current, though both pleasant and unpleasant olfactory stimuli were sometimes used. The fluctuations were measured and averaged and the length of

[1] Psychological Rev., Vol. X, pp. 120 ff.

the total wave as well as the attention efficiency under the influence of stimulation compared with the normal length and efficiency. Of the three subjects used the first gave a decrease of 3.6 sec. in the length of the total wave under unpleasant stimulation and an increase of .4 sec. under pleasant stimulation. The attention efficiency varied directly with the length of the total wave. With the second subject all stimuli, whether pleasant or unpleasant, increased the length of the wave an average of 1 sec. and heightened the efficiency. With the third subject the length of the total wave was uniformly increased but the efficiency was sometimes increased and sometimes the reverse. In the case of the first subject the respiration waves varied with the attention waves while in the other cases the breathing waves were shortened and the attention waves lengthened.

In the face of these apparently contradictory results we must agree with Taylor that each subject must be studied separately. The fact of wide individual variations is shown clearly. It seems perfectly plain that, so far as the effect of sensory stimulation on the length of the attention waves and an attention efficiency is concerned, every individual is a law unto himself. It is no less plain on the other hand, that in most cases stimulation causes a lengthening of the total wave and along with this an increase in efficiency. The problem involves the study of a set of functions which are easily disturbed by any kind of interference and which are bound up with plastic structures in which wide individual variations on the one hand and the establishment of fixed tendencies on the other are to be expected. Thus the impossibility of discovering rigid and narrow rules which are valid for all subjects is evident at the start; but it is possible to show the existence of general laws holding throughout the various types to which the particular cases may be reduced.

For further evidence of the necessity of this method we may turn to Prof. Pillsbury's work on attention waves and fatigue. In these experiments the fluctuations were recorded on the horizontal drum used by Taylor. Four records per day were taken from each subject with the exception of one man whose afternoon record was omitted. The records were taken at about 9:00 A. M., at noon, at about 2:00 P. M., and at 6 P. M. It was found that the length of the attention wave and the attention efficiency have a diurnal periodicity relatively constant for each individual while the curves of different individuals vary widely, and further that this curve indicated the type of worker to which the subject belonged. It appeared, also, that in every case "the greater length of wave corresponds to the time of greatest attention efficiency," which confirms the general con-

clusion we drew from Taylor's work. The fact that this relation held for all six of the subjects used, and through a series of experiments extending for most of them over a considerable period of time, is suggestive. In connection with the previous work the results would seem to point directly to the central origin and control of the fluctuations.

Summing up the work thus far we may conclude:

1. That in most subjects the attention waves stand in close relation to the Traube-Hering waves, while in a minority of cases there is an equally well defined coincidence with the respiratory rhythm.

2. That voluntary effort and sensory stimulation increase attention efficiency in nearly every case.

3. That in the majority of cases the periods of greatest efficiency coincide with the periods of greatest wave length while in a few cases the reverse is true.

4. That similar individual variations occur in the effect of fatigue and sensory stimulation on the length of the attention wave while this effect is constant for particular individuals.

5. That the fluctuations show for each subject a diurnal periodicity of efficiency and wave length peculiar to that subject.

In view of these conclusions the necessity of further work on the Traube-Hering waves is plain. If Slaughter's theory has any basis in fact we should expect that in the great majority of subjects the vaso-motor waves would be affected by voluntary effort, by sensory stimulation and by fatigue in precisely the way in which the attention waves are affected by the same influences. More exactly we would expect: (1) that voluntary effort would increase the length of the Traube-Hering waves in those subjects whose records show an increase of attention efficiency to correspond to an increase in the length of the total wave, and that the opposite effect would be produced in those subjects whose records show the reverse of this relation; (2) that sensory stimulations would have the same effect on the length of the Traube--Hering waves as on the length of the attention waves, *i. e.*, would increase it in nearly every case; (3) and that the Traube-Hering waves would show *for each subject* a "diurnal periodicity corresponding to that noted in *his* attention waves." A similar correlation of attention and respiration would be expected in those subjects in whom the breathing rhythm plays the predominant part in determining the fluctuations of attention.

Our experiments were begun with the purpose of determining whether or not these apparent relations can be shown to exist. One difficulty presented itself at the outset. No direct comparison of our results with those obtained by Slaughter and

Taylor was possible, since we were obliged to use different subjects, and while Taylor's subjects showed very wide individual differences, our own, as will be seen, presented far less distinct differences of type. It will be shown later, I think, that this difficulty is not so serious as it first seems. On the other hand a very close correlation of our results on the diurnal changes in the length of the Traube-Hering waves with those on the changes in the attention waves was possible, for the same men were used as subjects throughout. This is important, for it enables us to emphasize the fact of individual differences on the one hand and the close agreement of attention and vaso-motor or respiratory rhythms on the other, and on this basis to explain the apparent opposition between our results and those previously reached.

In our work upon the effect of stimulation on the length of the Traube-Hering waves the tracings were taken on the drum of an ordinary vertical kymograph. The pulse tracings were recorded by means of the delicate piston-recorder attached to the finger-plethysmograph or by the Hallion-Comte plethysmograph in connection with a Marey tambour. A pneumograph attached to a Marey tambour registered the changes in respiration and the time was recorded by a Jacquet chronograph. The pointers were set in a vertical line so that any disturbances in the respiration and pulse tracings could be carefully compared. The time required for a revolution of the drum was about five minutes and each record lasted through two revolutions. During the first an effort was made to eliminate every disturbance and secure a perfectly normal tracing; during the second the stimulus was applied. This stimulus was commonly an induction current passed through the free hand, but with three of the subjects pleasant and unpleasant gustatory and olfactory stimuli were sometimes substituted. The Traube-Hering waves were projected on a straight line and there measured. The averages were taken and the effect of stimulus on the length of the wave determined for each record, after which the whole series was averaged for each observer.

The experiments extended through the greater part of the year. Five subjects were used: Prof. Pillsbury (P), Dr. Wallin (W), Mr. Hayden (H), Mr. Freund (F) and the writer (G).

The results were remarkably uniform. The absolute length of the waves varied considerably for each subject from day to day, but the ratio of the average normal wave to the average wave taken with stimulus was very nearly constant. The following table gives the results in averages.

(The first column gives the subject's name; the second the total number of records taken; the third the average length of

TABLE I.

SUBJECT.	NO. OF REC'DS.	NORMAL.	STIMULUS.	S.—N.
P	27	9.4	11.5	2.1
W	9	10.0	12.4	2.4
H	32	9.6	10.8	1.2
F	14	9.9	12.5	2.6
G	26	10.1	12.5	2.4

the normal Traube-Hering waves for the entire series; the fourth the average length of the wave taken with stimulus; the fifth the average increase in length resulting from stimulation).

In 105 of the 108 records taken the stimulation caused a distinct lengthening of the waves. In two of the remaining three very weak olfactory stimuli were used and no change in the length of the wave resulted. The third record was taken as a curiosity. The subject had complained of headache and nausea before work was begun. Strong vaso-constriction, weak pulse, and slightly shortened Traube-Hering waves resulted from the stimulation with the induction current. In all the other cases the waves were lengthened, with total indifference to the pleasantness or unpleasantness of the stimulus. The effect of the pleasant and unpleasant olfactory and gustatory stimuli was precisely the same as that of the painful induction current. An abrupt change from a very pleasant to an unpleasant stimulus or *vice versa*, and even several such changes in the course of a single record, produced exactly the same result as the constant stimulus.

Assuming the validity of the conclusions reached by Slaughter and Taylor these are the results we should expect. Taylor's work showed that no general rule for the effect of stimuli on the length of the attention waves valid, for all subjects, can be reached, but that in most cases the wave length is increased and that efficiency generally varies directly with the wave length. Since, as Prof. Pillsbury found, increase in wave length and increase in efficiency do coincide in the case of the five subjects from whom our results were taken, the lengthening of the Traube-Hering waves by stimulation is what must have happened on the basis of the central theory; and Taylor's mixed case, so far from contradicting our results tends indirectly to confirm them.

It will be remembered that Slaughter found that voluntary effort increased the efficiency of attention but shortened the total wave. In the hope of securing further evidence for the central theory Mr. Sherman, who was then doing some work

involving the use of the ergograph, took several pulse tracings to determine the effect of effort on the Traube-Hering waves. The experiments were conducted in practically the same way as those in which the effect of sensory stimulation was being investigated. The observers were Mr. Sherman (S) and Mr. Hayden (H). The records were turned over to the writer and the averages are given in the following table.

TABLE II.

SUBJECT.	NO. OF REC'DS.	NORMAL.	VOLUNTARY EFFORT.	V. E.—N.
S	7	7.5	9.2	1.7
H	10	7.6	9.1	1.5

The effect of voluntary effort was, in each case, to increase the length of the vaso-motor waves which is directly opposed to Slaughter's results. On the other hand he found that the efficiency of attention was increased and in the case of our subjects' increase of efficiency coincides with increase of wave-length. Further there is no reason to suppose that voluntary effort any more than sensory stimulation must affect all persons alike, and it seems probable, as I hope to show, that the effects of effort and stimulation on the Traube-Hering waves must be identical. Finally, and most important, it was found in records previously taken that in both of these subjects voluntary effort increased the length of the attention waves.

It now becomes necessary to bring forward some physiological explanation of this change in the lengths of the vaso-motor waves. The fact that sensory stimulation and voluntary effort affect the vaso-motor waves, in most cases to lengthen them, seems quite beyond dispute, but how this effect is produced is not evident. It is generally supposed that the Traube-Hering waves are due to a periodic excitation of the vaso-motor centre by cyclic changes in the blood pressure at the medulla.[1] Anæmia of the medulla excites the centre and causes a constriction of the peripheral vessels and a consequent rise of the arterial pressure, at which the excitation ceases and the pressure is allowed to fall, anæmia of the medulla results and the round is repeated. The explanation is, however, complicated by the fact that vaso-dilation as well as vaso-constriction is, from the point of view of nervous physiology, an active process. The vaso-motor nerves contain both constrictor and dilator fibres, and a complete Traube-Hering wave involves the activity of both.[2] The fact that vaso-constriction rather than vaso-dilation

[1] Schäfer: Physiology, Vol. II, p. 139. [2] *Ibid.*, pp. 132-134.

follows an excitation of the vaso-motor centre is doubtless due to the fact that the latent period of the vaso-constrictor fibres is but little more than one-third as long as that of the vaso-dilation fibres.[1] It has been shown experimentally that "if the vaso-constrictors and dilators are stimulated simultaneously, the constrictor influence at first overpowers the dilator. The dilator effect, however, appears afterward, for the vaso-dilator fibres are less easily exhausted.[2] That is "the vaso-dilator effect appears after a longer latent period, while it reaches its maximum and disappears more slowly."[3] We would therefore expect to find the Traube-Hering waves in the pulse tracings divisible into a shorter descending section representing the period of vaso-constriction and a longer less steep ascending section representing the period of vaso-dilation. A careful examination of our plethysmographic records was made, and it was found that this relation between the two parts of the wave held for the averages of a large number of measurements, but where only a few waves were measured the reverse of this relation or an exaggeration of it was found. These irregularities were traceable to interference from the respiratory centre and from external stimulations.

The fact that many, if not all, external stimuli cause an initial fall in the volume curve is beyond question, and the only reasonable explanation of this seems to be that here is an irradiation from the sensory centres upon the vaso-motor centre causing immediate stimulation of the constrictor fibres. The overflow of impulses from a sensory to a motor centre is a well established fact of nerve physiology, so this explanation presents no difficulties of theory; and the equally well established fact of the overflow from one motor centre to another accounts for the effect of voluntary effort and demands that this effect be precisely the same as that of sensory stimulation. We would expect, then, on the basis of purely theoretical considerations that the effect of sensory stimulation or voluntary effort on the vaso-motor nerves would be somewhat as follows: There would be an overflow of impulses upon the vaso-motor centre causing increased excitation of both constrictor and dilator fibres. If the activities of the two were precisely alike no change in the volume-curve would take place; but owing to the shorter latent period and greater excitability of the constrictor fibres there would be an initial constriction and a hastening of the constrictor effect which would thus reach its maximum more quickly than under normal conditions, and this part of the wave would be shortened. Since, however, the

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[1] Schäfer: Physiology, Vol. II, p. 135.
[2] *Ibid.*, p. 134.
[3] *Ibid.*, p. 135.

dilator effect reaches its maximum and disappears more slowly the decrease in the length of the constriction would be somewhat more than balanced by a proportional or more than proportional increase in the length of the dilation and the effect would be an increase in the length of the total wave. The constrictor effect would be hurried to its maximum and would disappear under the combined influences of exhaustion and the opposition of the increased dilator activity. Then, since the dilator fibres are less easily exhausted and have no further opposition, vaso-dilation would continue beyond the normal period, its maximum effect is increased and consequently the time required for its disappearance is greater than when no reinforcement was present. The relative change of length would probably be slightly greater in the period of constriction, but even if this were true the final result would be an increase in the length of the whole wave owing to the greater length of the normal dilation. Further examination of the pulse tracings showed that in spite of many irregularities and variations the increase in wave-length under stimulation was due to an increase in the length of the period of dilation while the length of the period of constriction was decreased. We were, of course, obliged to use averages, no direct comparison being possible. The general effect is well brought out in Table III taken from a somewhat exceptional record.

TABLE III.

N.	Nd.	Nc.	S.	Sd.	Sc.
10	6	4	11	8	3
7	4	3	12	8	4
12	7	5	9	7	2
10	7	3	11	6	5
10	6	4	11	9	2
10	6	4	11	6	5
8	5	3	14	10	4
9	6	3	8	6	2
8	5	3	11	9	2
12	7	5	12	9	3
7	4	3	10	8	2
11	6	5	10	8	2
9.5	5.7	3.8	10.8	7.8	3

(The column headed N gives the length of 12 successive waves from the middle of a normal tracing. The columns headed N d and N c give the periods of vaso-dilation and vaso-

constriction in each wave. The columns S, S d and S c give the same for the middle portion of the corresponding record taken with stimulation. The averages are at the bottom of the column. It will be seen that the lengthening of the waves averages 1.3 sec. The average increase in length of the dilation is 2.1 sec., while there is a decrease of the difference, .8 sec., in the length of the constriction.)

It now seems evident that any reinforcement of the medullary centres from the cortex, whether from sensory or motor activity, should produce an increase in the length of the Traube-Hering wave. In any case the source and character of the stimulus should make no difference in the effect. Against these conclusions, however, we have Slaughter's statement that voluntary effort produced a decrease in the length of the attention wave. Two explanatious of this may be suggested, but an examination of his records and of pulse tracings from the subjects from whom his results were obtained, would be necessary to decide which is to be accepted. It is possible that the respiratory rhythm determined the fluctuations of attention in the cases in question and our records show that in nearly every case reinforcement of the medullary centres quickens respiration. It is also possible that in these subjects there was an unusually close balance between the activities of the constrictor and dilator waves. The records taken from H show a very close balance between the length of the constrictor and dilator periods, and reference to Table I shows that the increase of wave length caused by stimulation is only about one-half as great as in the other four cases. That in some individuals the opposite of the usual relation holds is uncertain but not impossible or even improbable.

We pass now to a consideration of the daily rhythm of the Traube-Hering waves. The apparatus was the same employed in the investigation of stimulus effects. Four records per day were taken at the hours on which Prof. Pillsbury had taken his records in the experiments described above. Each record lasted from five to ten minutes and showed from fourteen to sixty-two Traube-Hering waves. The subjects were those from whom the results of Table I were obtained and from whom Prof. Pillsbury's records had been taken. In the cases of all the subjects except F some months elapsed between the times when the records for the daily rhythm of the attention waves and those for the daily rhythm of the vaso-motor waves were taken. The comparison must, therefore, be of averages and a parallelism of tendency is all that can be expected. Where the attention waves of any subject show a uniform daily periodicity a corresponding periodicity should appear in the Traube-Hering waves, but the absolute lengths, even when the averages are

used, would almost certainly differ. The following tables give the results which are obtained and show the general correspondence expected. The attention measurements in the fourth column are copied from Prof. Pillsbury's tables in his articles on Attention Waves as a Means of Measuring Fatigue.[1]

[1] *Am. Jour. of Psy.*, Vol. XIV, 277.

TABLE IV.

P.

TIME.	NO.	T.-H.	ATT.
9.00 A. M.	106	10.0	9.6
Noon	88	9.2	8.5
2.00 P. M.	102	9.0	8.2
5.30 P. M.	124	8.6	7.5

TABLE V.

W.

TIME.	NO.	T.-H.	ATT.
9.00 A. M.	107	9.9	5.4
Noon.	116	10.4	6.3
2.00 P. M.	114	9.0	
5.30 P. M.	98	8.3	5.1

TABLE VI.

H.

TIME.	NO.	T.-H.	ATT.
9.00 A. M.	367	9.5	9.4
Noon.	316	8.4	8.6
2.00 P. M.	483	8.9	9.1
5.30 P. M.	252	8.0	8.4

TABLE VII.

F.

TIME.	NO.	T.-H.	ATT.
9.00 A. M.	80	9.4	18.9
Noon.	96	9.0	18.2
2.00 P. M.	87	6.3	13.4
5.30 P. M.	111	9.5	18.5

TABLE VIII.

G.

TIME.	NO.	T.–H.	ATT.
9.00 A. M.	174	8.8	8.9
Noon.	160	8.9	8.9
2.00 P. M.	203	8.4	8.4
5.30 P. M.	178	8.6	8.4

(The first column gives the time of day when the records were taken; the column headed No. gives the total number of waves measured; that headed T—H the average length of the Traube-Hering waves; and that headed Att., the corresponding measurements of the attention waves.)

In Table IV the general correspondence between the vaso-motor and attention rhythms is evident in spite of the greater length of the vaso-motor waves. In explanation of this difference in length it is enough to say that the records for the attention waves were taken in the middle of July while those for the Traube-Hering waves were taken in mid-winter and under very different conditions. Why the difference should be in this direction rather than the opposite it is impossible to say, but that there should be some difference was to be expected. What is significant for us here is the fact that there is a general decrease in the length of both the attention and the Traube-Hering waves from morning to night, a parallelism which can scarcely be accounted for save on the assumption of a common physiological basis.

In table V two interesting features are presented: (1) There is the evident correspondence between the attention and respiratory rhythms, shown by the very short attention waves; and (2) the fact that these waves show a definite daily periodicity which corresponds with that of the Traube-Hering waves. There is an increase in the length of both attention and Traube-Hering waves until noon and a decrease in the afternoon. This parallelism is readily explained by the fact that in the normal records the vaso-motor and respiratory activities seem always to vary in the same direction.

In Table VI the correspondence is much closer than in either of the two preceding cases. Not only are the absolute lengths nearly the same but the peculiar daily periodicity of the one is very accurately repeated in the other. Attention and vaso-motor waves show a decrease in length in the morning, a rapid recovery during the noon rest and again a marked decrease through the afternoon.

Table VII presents a new complication. The attention waves are about twice the length of those taken from the other subjects and almost exactly double the length of the Traube-Hering waves. As the two series were in this case taken within a few days of each other a fairly close correspondence of the absolute lengths would be expected. As for the two-to-one relation it seems probable that there is a summation effect at its basis, influenced also, perhaps, as the records suggest, by coincident reinforcement from the respiratory centre. But here, again, the important fact is that there is a very definite and constant relation between the two series indicating a common physiological basis.

In Table VIII the parellelism is so close that it may be allowed to pass without comment. The absolute lengths, as shown by the averages, are almost exactly the same for all four periods.

The significance of the results shown in these tables is unmistakable. The fact that the attention and Traube-Hering waves have the same daily variation is in direct line with Slaughter's conclusions and is one more bit of evidence that the two rhythms are causally related or at least have a common basis. Even if Slaughter's explanation of the relation between them is incorrect the relation itself would seem to be pretty thoroughly established.

It would seem to be of interest in the general controversy as to the effects of pleasantness and unpleasantness upon circulatory phenomenon, that all stimuli of any intensity have exactly the same influence upon the length of the Traube-Hering waves. Evidently here there is no trace of an opposed relation between pleasantness and unpleasantness.

SUMMARY.

1. Traube-Hering waves are increased in length for each of five subjects by stimuli whether pleasant or unpleasant.
2. Muscular contraction, for two subjects, increased the length of the waves.
3. The daily variation in the length of vaso-motor waves is in the same direction as in the attention waves from the same subjects.

If we bring these results into connection with the effect of similar stimuli on attention waves, the argument would run, that Traube-Hering like attention waves are influenced by stimuli of all kinds, and that the universal direction of change for all our subjects was the same as for the majority of those whose attention waves have been studied. That there is great probability of individual variation, and that

subjects will be found for whom stimuli of suitable strength would quicken the rate of the Traube-Hering wave, is not unlikely. Only simultaneous records of attention and Traube-Hering waves can decide this point.

The similarity in the dirurnal variation and the close approximation in length of the two sorts of waves in three subjects, in spite of the different times at which the two investigations were carried on, make very strongly for the common physiological basis of the processes.

VIII. The Effects of Closing the Eyes upon the Fluctuations of the Attention.

By Bertha Killen.

Münsterberg's peripheral theory takes the stand that the fluctuations of the attention are due to the fatigue and recovery of the accommodation mechanisms in the sense organ. He made a number of elaborately varied experiments upon the sense of sight. His method of experimentation was to fixate the gray rings of the Masson disk and record the fluctuations in series upon a white kymograph drum by means of a tambour and pencil. The general average of the normal fluctuations was first established at 6.9 seconds. He then varied his experiments by use of a "*prismatische lorgnett*" by means of which the field of vision was moved slightly to the side, requiring a quick movement of the eyes in order to keep the fixation continuous. In case the prisms were held continuously before the eyes, no very great change in the fluctuations would appear. But when the glass was interposed at intervals of two seconds it was found that the fluctuations could be lengthened from 11 to 14 seconds. In the next series, a sound was made by an assistant, every second, which caused the subject to close the eyes quickly for a moment, making a scarcely noticeable break in the fixation. Under these circumstances a decrease to entire vanishing never took place. But when the disk was covered at intervals by a screen the fluctuations went on unhindered.

In view of the fact that Pace recently used these results as a proof of the peripheral or retinal origin of the attention waves, it seemed worth while to repeat them to test their accuracy. Münsterberg argues from these results that the momentary rest permitted the eyes to recover from fatigue.

The subjects were Miss Udell (U.), Miss Barnes (B.), and Mr. Wright (W.), all research students in psychology and were careful, experienced subjects.

The experiments were carried on from September to February, 1903-04. In the case of U. and B. a normal and a modified